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ALERTMESH: An Adaptive ESP32 Mesh Communication System for Network-Disconnected Disaster Areas

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ABSTRACT

Communication is essential during disasters, especially when conventional cellular networks and internet infrastructure become unavailable or unreliable. This study developed ALERTMESH, an adaptive ESP32-based mesh communication system designed to exchange messages without relying on cellular networks or internet connectivity. The prototype was tested to determine its communication range and performance under sunny, cloudy, and rainy weather conditions, as well as in open and obstructed environments. Results showed that ALERTMESH could support message exchange under different conditions, although its performance was affected by transmission range, environmental obstructions, weather conditions, and GPS limitations. Despite these constraints, the system demonstrated potential as an alternative communication system during network disruptions. Future improvements may include adding voice-message features, using sustainable power sources, upgrading GPS modules, and utilizing a microcontroller with higher RAM capacity.

Keywords: ALERTMESH, ESP32, mesh communication, disaster communication, GPS, emergency communication

1. INTRODUCTION

Reliable communication systems support emergency response, public safety, and the exchange of critical information during disasters (Usmonov, 2025). However, cellular and radio networks are vulnerable to earthquakes, typhoons, floods, and strong winds, which may damage infrastructure, interrupt power supply, or overload communication services during emergencies (Matracia et al., 2022; ITU, 2025). For instance, Hurricane Harvey caused 360 cell towers to lose service, showing how conventional communication infrastructure can be affected during major disasters (Feeny et al., 2026). When these systems become unavailable, affected communities may experience difficulties in sending emergency messages, requesting assistance, and coordinating response activities.

This concern is particularly relevant in the Philippines, where communities are frequently exposed to typhoons, floods, earthquakes, volcanic eruptions, and landslides. These hazards can damage communication facilities and power infrastructure, resulting in service interruptions that affect emergency coordination. During Typhoon Uwan, unstable connections affected parts of Antique, Guimaras, and Iloilo, while 388 of 809 Free Wi-Fi sites in Western Visayas experienced downtime (Garion, 2025). Similarly, San Miguel, Bulacan faces risks from typhoons, heavy rainfall, and flooding, which may affect communication during severe weather events. As a result, communication systems that can function independently of conventional networks may provide an additional option for maintaining information exchange during emergencies.

In response to this concern, researchers have examined decentralized mesh networks and off-grid communication systems that can support communication without relying entirely on cellular networks or internet services (Kadiyala & G, 2026). These approaches allow devices to communicate through connected nodes and local networks, making them applicable to situations where conventional infrastructure is unavailable. The ESP32 Wireless Adventure describes the ESP32 as a low-cost microcontroller with Wi-Fi capabilities that can support wireless communication and IoT applications. These features provide a technical basis for developing localized communication systems that can support information exchange during network disruptions.

Building on these concepts, ALERTMESH was developed as an ESP32-based communication system intended to support local messaging during network disruptions. The study focused on developing an emergency messaging framework, extending communication between nodes through ESP-MESH, and configuring local web interfaces that allow users to exchange messages without internet access. The prototype used three ESP32 nodes and was tested three times at San Miguel National High School using one Android and one iOS device. The testing covered sunny, rainy, and cloudy weather conditions, along with open, obstructed, and vertical transmission setups. The evaluation examined communication range, connection stability, message transmission, reliability, and GPS functionality.

Furthermore, the study may provide useful information for groups involved in education, disaster preparedness, and communication technology. Teachers may use the study as a resource for lessons involving disaster risk reduction, electronics, information technology, and communication systems. Schools may also consider its concepts when developing disaster preparedness activities and technology-based research. Communities may benefit from an additional communication option for sharing emergency information when conventional services are disrupted, while future researchers may use the study as a reference for further work involving ESP32 networks, mesh communication, GPS-based systems, and disaster-resilient technologies.

Despite these potential applications, the study has several limitations. The prototype was limited to three ESP32 nodes, a 155-character message capacity, and the coverage area of the network. Testing was conducted only at San Miguel National High School and under the specified environmental conditions using one Android and one iOS device. The system was developed as an alternative communication prototype and was not intended to replace cellular networks, internet services, or official emergency communication systems. These limitations define the conditions under which the findings of the study should be considered.

1.1 Statement of the Problem

This study focused on developing ALERTMESH, an adaptive ESP32-based mesh communication system designed to facilitate fast and accessible communication without relying on cellular towers or internet infrastructures. It aimed to provide an alternative and reliable means of exchanging messages during disasters and other critical situations when conventional communication networks are unavailable or disrupted. Specifically, this study sought to answer the following questions:

1. What is the maximum communication range of the ALERTMESH prototype in terms of:
 - 1.1. Vertical transmission distance; and
 - 1.2. Horizontal transmission distance?
2. How does the ALERTMESH prototype perform under different weather conditions in terms of:
 - 2.1. Sunny weather;
 - 2.2. Rainy weather; and
 - 2.3. Cloudy weather?
3. How does the ALERTMESH prototype perform in different environmental set-ups in terms of:
 - 3.1. Indoor or obstructed spaces; and
 - 3.2. Open spaces?

2. METHODOLOGY

2.1 Materials and Sample Collection

Before the device was assembled, all necessary hardware components were recognized and prepared. Table 1 presents the components required for this device, involving their quantities, online sources, and their prices.

Table 1. List of Materials

Components	Quantity (Per Package)	Location or Source	Price
ESP32 WROOM-32 (38 Pin)	3	MakerLab	Php. 1155
NEO-6M GPS Module	1	MakerLab	Php. 299
Male-Female Jumper Wires	1	ENG LAB.ph	Php. 56
Micro-USB Cable	1	Jericho San Juan	Php. 130
Power Bank	3	Researchers	-
TOTAL			Php. 1640

2.2 Device Assembly

Figure 1 showed that during assembly, a power bank was used as the microcontroller's power source. The ESP32 was tested using a voltmeter to check if the 5V and GND pins emit electrical current when powered. These pins supplied power to the GPS module. Then, the NEO-6M GPS Module was

connected to the node using male-female jumper wires. Only nodes with GPS modules were flashed with code that allowed the microcontroller to send its location to other nodes.

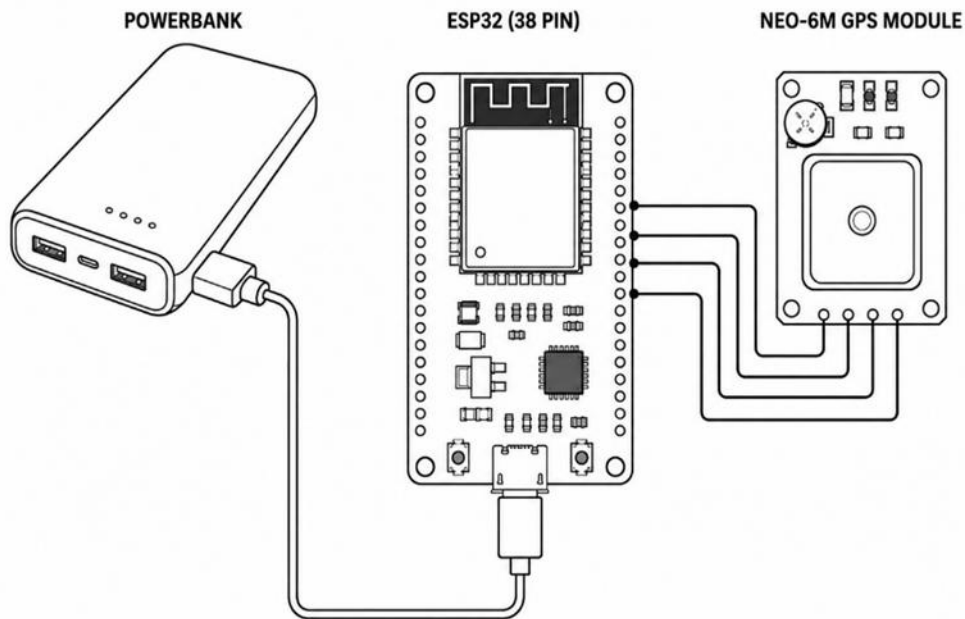


Figure 1. Physical Layout of the Device Prototype (Node A)

2.3 Installation of Firmware

A custom code was created using HTML and CSS, featuring top indicators for connected nodes and their status (active, inactive, or out of range), a messaging area with a send button, a one-touch SOS emergency button with GPS broadcasting, and a bottom GPS location display. Along this, the program that allowed the microcontrollers to emit their own WIFI signal was developed. After that, the code was uploaded to each microcontroller.

2.4. Debugging and Maintenance

Code errors and communication issues identified during testing were debugged and resolved with technical guidance. Following this, system maintenance involved inspecting the hardware for loose wiring, moisture, and debris to ensure safe operation.

2.5. System Evaluation

The prototype underwent system evaluations to determine its effectiveness. It was subjected to conditions like obstructed spaces, open spaces, building floors, sunny weather, cloudy weather, and raining. The nodes were left in designated spots while the mobile devices were moved away. This was also done with one node to another. The researcher then recorded the results of the tests.

2.6. Data Analysis

The data collected during the system evaluation were organized and analysed. The results from the message transmission, GPS, and communication range tests were recorded and arranged in tables. The researcher analysed the number of successfully transmitted messages, communication failures, and the maximum distance reached by the communication network. The GPS results were also tested to determine if the latitude and longitude information was successfully detected and displayed.

3. RESULTS

In this stage of the study, the results of the developed were presented. The prototype was tested to determine its effectivity when exposed to different scenarios. The gathered data were arranged in tables and were discussed to show how reliable and effective the messaging was.

3.1 The effectiveness of ALERTMESH in terms of horizontal and vertical transmission distance

This part shows the horizontal and vertical transmission distance of the device. The test was done to determine the maximum span for communication using the device. Along this, the GPS Module was also tested to see if satellites can be detected. The data gathered were summarized into tables to show the effectiveness of the device.

Table 2. Horizontal and Vertical Transmission Distance

Axis	Test Number	Android	IOS	GPS
Vertical	1	8m	8m	Yes
Vertical	2	8m	8m	Yes
Vertical	3	8m	8m	Yes
Horizontal	1	55m	55m	Yes
Horizontal	2	70m	70m	Yes
Horizontal	3	80m	80m	Yes

The horizontal and vertical transmission performance of the ALERTMESH prototype was evaluated at San Miguel National High School to determine its communication capability across different distances and building levels. Three trials were conducted using Android and iOS devices.

For vertical transmission, both devices successfully exchanged messages across an 8-meter distance between the fourth and third floors, the third and second floors, and the second and first floors. The consistent results showed that ALERTMESH maintained communication between adjacent building levels despite structural barriers.

For horizontal transmission, both devices reached 55 meters in Test 1, 70 meters in Test 2, and 80 meters in Test 3. The identical results for Android and iOS indicated that the mobile operating system did not affect the transmission distance. GPS location sharing also functioned properly throughout all horizontal and vertical trials.

Overall, ALERTMESH provided stable communication on Android and iOS devices, reaching a maximum tested distance of 80 meters horizontally and 8 meters vertically. The results also demonstrated the consistent functionality of its GPS location sharing feature.

3.2 The effectivity of ALERTMESH in terms of different weather conditions

This part shows the results of the device under weather conditions like sunny, rainy, and cloudy. The testing was done to determine if there was a change in signal strength between nodes and devices. Along this, the GPS Module was also tested to see if it can detect satellites. The data gathered were summarized into tables to show the effectivity of the device.

Table 3. Weather Condition Test

Weather Condition	Test Number	Android	IOS	GPS
Rainy	1	50m	45m	No
Rainy	2	65m	65m	No
Rainy	3	80m	80m	No
Cloudy	1	50m	45m	No
Cloudy	2	65m	60m	No
Cloudy	3	80m	80m	No
Sunny	1	55m	55m	Yes
Sunny	2	70m	65m	Yes
Sunny	3	80m	80m	Yes

Table 3 shows that the device emitted signal strengths and GPS results. The tests were repeated 3 times to ensure that the data is accurate. In the case of inconsistencies, the mean from the 3 tests will be taken to determine its effectivity radius.

The device underwent testing under a rainy weather condition up to a transmission distance of 85 meters. There is a total of three tests using an Android and IOS device to determine the effects to the device during a rainy weather. In Test 1, both devices were able to transmit and receive messages with a moderate signal wherein the Android reached a range of 50 meters and the IOS device reaching 45 meters. In Test 2, the devices exceeded to a coverage of 65 meters, message transmission remained successful while the signal became medium. In Test 3, both devices reached the maximized range of 80 meters in which the connection quality varied between low and medium signal while remaining the ability to transmit and receive messages. However, GPS location was unavailable due to the rainfall obstructing the GPS signal reception. These results indicate that the prototype can still provide communication during rainy weather even though the GPS functionality may be affected.

The performance of the ALERTMESH prototype was examined under a cloudy weather condition within a distance of 85 meters. The testing occurred three times using one Android and one IOS device which were connected through the three ESP32 nodes to evaluate the effects of the cloudy weather to the communication device. In Test 1, the Android covered 50 meters whereas the IOS device attained 45 meters where both devices were able to communicate with each other by sending and receiving messages while maintaining a moderate signal. In Test 2, while the Android reached 65 meters, the IOS device had a span of 60 meters in which the transmission and receive of messages still continues with a medium signal. In the last test, both devices hit a distance of 80 meters while they successfully transmit and receive messages while maintaining a medium signal. During the trials, the GPS did not function properly because the cloudiness affected the GPS signal reception. The results highlights that the prototype maintained reliable communication within 80 meters, meanwhile the GPS functionality was limited under cloudy weather conditions.

The capabilities of the communication device were assessed under a sunny weather condition which is tested at range of 85 meters. A total of three experimental trials will be conducted to determine the effects of a sunny weather on the prototype. In Test 1, both devices reached a span of 55 meters and smoothly exchanged messages with a moderate connection. In Test 2, the Android device reached 70 meters while the IOS device reached 65 meters while maintaining the ability to send and receive messages with a medium signal. On the final test, both devices reached a range of 80 meter and were able to transmit and receive messages while maintaining the medium connection. The GPS location functioned properly and maintained stable during all the trials. This establishes that the ALERTMESH prototype provided stable communication and GPS functionality under a sunny weather.

3.3 The effectiveness of the device's messaging system in different environmental conditions

This study evaluated how well ALERTMESH delivers messages in conditions like Obstructed, Unobstructed, and Building conditions. The test measured if the device can effectively relay messages when there are interferences in the way. This test is important as in emergency situations, obstructions cannot be avoided.

Table 4. *The Effectiveness of the Device in Different Environmental Conditions*

Environmental Condition	Test Number	Android	IOS	GPS
Obstructed	1	33m	30m	Yes
Obstructed	2	38m	36m	Yes
Obstructed	3	40m	40m	Yes
Unobstructed	1	55m	55m	Yes
Unobstructed	2	70m	70m	Yes
Unobstructed	3	80m	80m	Yes

The ALERTMESH prototype underwent testing in an obstructed environment at a range of 45 meters. A total of three trials were conducted using one Android and IOS device to determine the effects of physical barriers on the communication, and GPS functionality. In Test 1 the Android reached 33 meters and the IOS device with a distance of 30 meters, both devices successfully transmitted and received messages while maintaining a stable, mid-range signal. In Test 2, Android covered a distance of 38 meters and the IOS device with 36 meters, while maintaining functionality of the device to send, and receive message the signal is then shifting between intermediate and low RSSI (Received Signal Strength Indicator). In the last trial both devices maximize the range of the signal to 40 meters which is maximized due to the presence of an obstruction along the way, and the communication device successfully transmitted and received messages during the last trial. The GPS location sharing remained functioning all throughout all of the trials. The results shows that the prototype can still maintain communication within the communication range unless if there is any obstruction in the environment which can affect the maximum range of the communication device.

The performance of the ALERTMESH prototype was evaluated in an open-space environment at a distance of 85 meters. Three trials were conducted using one Android and IOS device to determine the communication range, if the GPS is functional and effectiveness of the communication device in an area with minimal obstructions. In Test 1, both devices reached a distance of 55 meters with a medium signal and delay in the transmission of messages. In Test 2, both the IOS and Android device increased its transmission distance to 70 meters, wherein the prototype successfully transmits the messages through each node with a delay of 20 seconds while maintaining a medium signal. In Test 3, both devices exceeded its range to 80 meters, the prototype remained successful in transmitting messages with a medium signal. In terms of the GPS location, in Test 1, 2, and 3 the GPS functioned successfully

during all the trials. The findings indicate that the prototype achieved reliable communication and GPS performance in open spaces within a distance of 80 meters.

4. Recommendations

Based on the findings of the study, several recommendations are proposed to improve the performance and functionality of ALERTMESH. These suggestions may guide future researchers in addressing the limitations observed in message transmission, power supply, GPS functionality, and storage capacity. Through these improvements, ALERTMESH may become a more reliable and practical communication system for network disconnected disaster areas.

1. Integrate a voice message feature to provide users with another way of communicating, particularly when typing is difficult during emergency situations.
2. Replace the power bank with a more sustainable power source, such as a solar powered system, to reduce the need for frequent manual charging and support longer operation during power outages.
3. Utilize higher quality GPS modules to improve the accuracy, stability, and availability of location coordinates under different weather and environmental conditions.
4. Install GPS modules on all available nodes so that each node can obtain and transmit location information independently during emergencies.
5. Use microcontrollers with greater RAM capacity to accommodate additional coordinates, messages, connected users, and future system features.

5. Conclusion

The ALERTMESH prototype successfully transmitted messages through three ESP32 nodes under different weather and environmental conditions. It reached up to 80 meters in open spaces and 8 meters vertically, while physical obstructions reduced its effective range to 40 meters. Communication remained functional during sunny, rainy, and cloudy conditions, although signal strength decreased at longer distances. GPS location sharing worked during open space, obstructed, sunny, and vertical tests but was unavailable during rainy and cloudy conditions. Overall, ALERTMESH demonstrated potential as an alternative communication system, although physical barriers and weather conditions affected its range, signal strength, and GPS performance.

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